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APPLICATIONS OF LOW PRESSURE FLUORESCENT LAMPS

By W. R. STEVENS, B.Sc. *(Fellow).*

(Communication No. 312. From the Staff of the Research Laboratories of the General Electric Company Limited, England.)

(Read on October 12th, 1943.)

SUMMARY.

The paper is concerned particularly with the 5 ft. fluorescent lamp which was evolved from the high-voltage fluorescent discharge lamps developed in England before the war. The design of fittings, particularly the diffusing trough, is described as a natural outcome of war-time restrictions and requirements. The results of some experiments to determine the optimum sizes of diffusing fittings are given and multi-lamp fittings are briefly considered. Specular reflectors are discussed to show some of the limitations of design imposed by the size and brightness of the source.

Installations of 5 ft. fluorescent lamps are illustrated to show the trend of modern good practice and some of the more important points are examined. Some possible future applications of the lamps are noted particularly their likely effect on building design in providing artificial daylight.

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(1) Introduction.

In the last few years there has been a greater fertility in the design of electric light sources than ever before. In particular there has been a concentration of effort on the possibilities of electric discharge through gases which has resulted in many new types. Discharges through mercury and sodium vapours, through neon and carbon dioxide gases, discharges with high and low gas pressures at high and low voltages have followed one another in such rapid succession that the fittings designer has been much occupied to exploit to the full the individual advantages of each lamp. (1)

One of the most recent of these is the low-voltage fluorescent discharge lamp (2, 3, 4). This is a natural outcome of the work pioneered in England long before the war, and which resulted in high-voltage tubular-fluorescent lamps, in which the discharge in the vapour or gas (generally mercury or neon) produces ultra-violet radiation, which excites a luminescent coating on the inner walls of the lamps (5). High efficiencies and a wide range of colours are thus obtained, and many installations have been erected both for exterior display (where the lamps are often still called "neon" sign lamps) and for interior lighting, where they have been woven into attractive shapes by skilled glass workers, and where combinations of colours give them an interest and attraction all their own.

Comparatively little was done on the design of fittings for these lamps. Their brightness is low and generally no diffusing material is required to make them comfortable to look at, and they can be made so attractive that additional decoration is unnecessary. Apart, therefore, from the simple reflectors required when high-voltage tubular-fluorescent lamps were built into cornices, fittings were not required.

Even in industry, where the lamps found a place in the lighting of gauge-rooms, bare lamps were found satisfactory. Their low brightness made them suitable even at comparatively low mounting heights, and their higher

efficiency and consequently smaller heat production than tungsten lamps, aided the maintenance of constant temperature and the avoidance of local "hot-spots."

There is no doubt that such lamps will play an important part in lighting in the future, but for the present, partly owing to war conditions, they have been displaced in this country by a low-voltage lamp working on a similar principle. This lamp, available at present in only one form and with colour-rendering properties similar to "daylight,"* seems to be regarded by many as the panacea to all our lighting ills, almost indeed as the "ultimate" in lamp design. It is a remarkable lamp, giving an average luminous efficiency some twice that of ordinary general lighting service tungsten filament lamps, and has already found many valuable uses. Because, however, of its low brightness it presents many difficulties to the fittings designer, and some of the most attractive uses prove difficult to put into practice.

It is not intended here to consider the lamp in detail—this has been done in many papers—but some of its properties must be remembered to discuss the fittings which might go with the lamp. Table I. gives some of these properties.

TABLE I.

Technical Data for 5-ft. 80-W Fluorescent Lamp.

Lamp Watts	80
Supply Voltage	200-250 A.C.
Length (overall) inches	60±0.5
Diameter inches	1½
Approx. Initial Light Output, lumens	3000
Brightness, candles per sq. inch	3-4

(2) Fittings for 5-ft. Tubular Fluorescent Lamps.

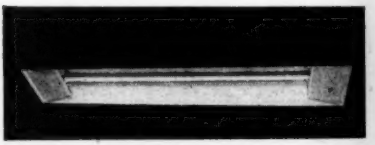
(2.1) DIFFUSING FITTINGS.

The most widely used fitting at present is the diffusing trough. In most installations the fitting is required to deflect downwards light which would otherwise escape to the ceiling, and as a natural development the over-reflector fitting has become the most common form.

Because of the large size of the lamp a rigid and robust material must be used. Glass is at a disadvantage because it must be enclosed in a metal housing to protect it from breakage. Most of the metals which could serve as specular reflectors and housings at the same time are not generally available during the war, and thus we can make only restricted use of aluminium and of chromium and nickel plated materials. We are largely dependent, therefore, on diffusing reflectors such as enamelled steel.

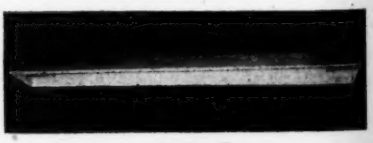
Vitreous enamelling, which has for many years been used for industrial lighting with tungsten lamps, presents difficulties with 5-ft. fittings because at the temperature at which the fittings are stoved they tend to distort, and although these difficulties can be overcome, most manufacturers use low temperature stoving enamel. There are several such enamels of high quality now available: they are durable and easy to clean, and are efficient light reflectors (of the order of 75 per cent.-80 per cent.) giving a high light output ratio to the fitting. The most serious drawback to the use of such enamels in lighting fittings has been the comparatively low temperatures at which they will operate without discolouring. In trough fittings using 80-W. lamps, however, the temperature rise of the housing is of the order of 10 C. deg., and in these conditions low temperature stoving enamel is usually satisfactory.

A reflector made of highly diffusing material will have a broad light distribution. One of the difficulties of such materials is the comparatively small control which they give to the designer, and, in fact, little can be done to vary the distribution obtained. Two such fittings are shown in Figs. 1 and 2. They are very different in shape although the cut-off angle of both is 70° to the downward vertical measured at right-angles to the lamp axis. The per-



Fitting A.

Fig. 1. Diffusing trough fitting for 80-W tubular fluorescent lamp.



Fitting B.

Fig. 2. Small diffusing trough fitting for 80-W tubular fluorescent lamp.

* True daylight varies widely in colour: the 5-ft. lamp corresponds approximately to noon sunlight.

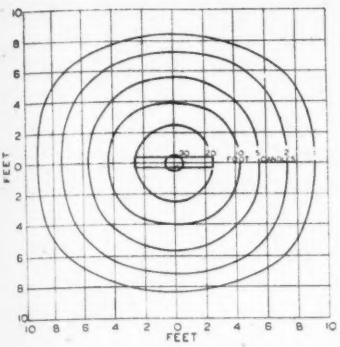


Fig. 3. Light distribution from diffusing trough fitting A. Mounting height 4 feet.

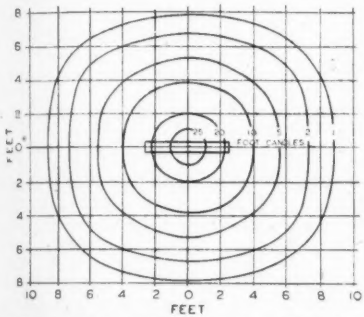


Fig. 4. Light distribution from diffusing trough fitting B. Mounting height 4 feet.

formance of the fittings can be portrayed by plotting the illumination distribution on a horizontal plane beneath the fitting. This is done in Fig. 3 for fitting A and Fig. 4 for fitting B for a plane 4 ft. below the fitting. If the reflectors were specular the distributions would be very different: with diffusing reflectors the difference is not great. Fitting A, which is larger, has slightly higher values than B, but the general shapes of the distributions have no differences of practical significance.

There is a difference of some 5 per cent. in light output ratio of the two fittings: A being larger saves light in two ways compared with B,

(a) Because the lamp offers less obstruction to light reflected from the enamel surface, and

(b) Because the lamp light output varies with its temperature, and in fitting A the lamp is operating more nearly at the optimum temperature.

(2.1.1) Obstruction Effect.

Light striking any part of the enamel reflector is reflected in all directions. Some of this light will escape immediately through the open reflector mouth, and some will be scattered back into the reflector. This light will suffer further reflection as a result of which some will escape from the fitting, but some will again be reflected into the fitting. If, however, the light after its first reflection falls on the lamp instead of emerging from the reflector, it will be reflected by the lamp. At this reflection some light is lost, and the process is repeated for the secondary and other reflections from the reflector.

If the reflector is small a good deal of the light will fall on the lamp after reflection from the fitting walls, and in this way the overall light output is considerably reduced: as the reflector size increases, the lamp size remaining constant, the obstruction effect of the lamp is decreased and the light output ratio of the fitting increased.

(2.1.2) Heating Effect.

The low-voltage fluorescent lamp has an optimum range of operating temperatures which is limited. The desirable temperature for the outside of the glass wall is about 50° C. Above or below this value the light output of the lamp tends to fall. The effect is complicated,

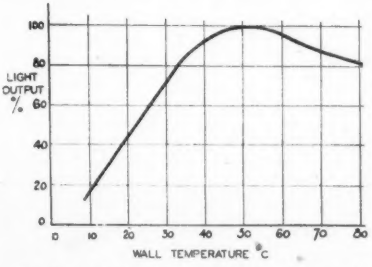


Fig. 5. Relation between light output and hall temperature for 80-W tubular fluorescent Lamp.

involving changes both in wattage consumption and efficiency of the lamp, and has been described elsewhere. Figure 5 shows the typical relation between wall temperature and light output.

In general, it is easy to design a fitting in which the lamp is sufficiently hot; the tendency with small fittings is for the lamp to overheat. This will not necessarily happen with proper design, and to some extent can be counteracted by suitable choke adjustment, but it is a

point on which the designer must take care. The loss is small (generally less than 5 per cent.), although not negligible for open troughs, but the effect will be greater for totally enclosed fittings. The problem naturally is most acute in fittings intended for very hot situations where the difficulty of cooling the lamp is great.

A consolation for the designer is that, although the lamp is sensitive to temperature, the wattage to be dissipated comes from so large a source at so low a temperature that difficulties due to overheating of leads and other component parts of the fitting are small. With most sources of light such overheating forms a large part of the problem of fittings design.

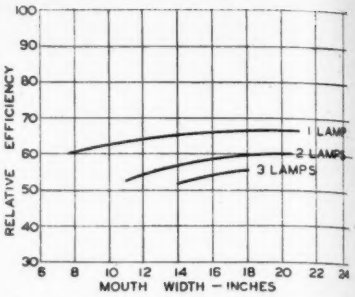


Fig. 8. Effect of size on light output. Ratio of diffusing trough fitting.

(2.1.3) Effect of Variations of Shape in Diffusing Trough Fittings

The result of the effects of obstruction and temperature change on diffusing trough fittings equipped with 5-ft. fluorescent lamps was examined by making experiments with the adjustable fitting illustrated in Fig. 6 and 7. The fitting size and shape could be altered between wide limits and relative efficiency values were obtained in a 10-ft. integrating sphere: the results are comparable although not correct in absolute value.

In the first set of experiments the width of the reflector mouth was varied, maintaining a constant cut-off angle (70 deg. to the downward vertical) and slope of sides (40 deg. to downward vertical). The results are shown in Fig. 8.

The top curve gives the result for a single lamp whose centre was 1¼-in. below the top of the reflector. With an 8-in. mouth width the relative light output ratio is 60 per cent., rising to 66 per cent. for a 14-in. mouth width: further increase in size has little effect. It is clear, therefore, that the fitting should not be too small but the balance between increasing light output ratio and increasing cost with increasing size of fitting can only be decided on economic grounds.

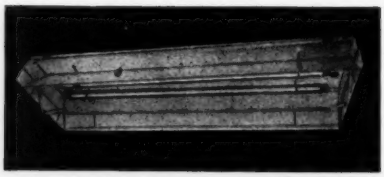
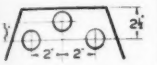
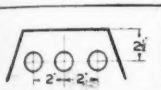
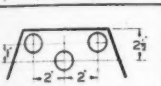


Fig. 6. Experimental adjustable fitting.

Fig. 7. Experimental adjustable fitting.

Similar results are shown for fittings having 2 and 3 lamps respectively: the lamps lay in the same horizontal plane 1¼-in. below the reflector top and with 2-in. between lamp centres. For a given size of reflector mouth the light output ratio decreases as the number of lamps increases, due again to the effects of obstruction and temperature change. For example with a 14-in. reflector the relative efficiencies for 1, 2, and 3 lamps are 66 per cent., 57 per cent., and 52 per cent., ratios of 1.0 : 0.87 : 0.79. This makes it clear that a number of single lamp units will be more economical in power consumption than the number of two-or three-lamp units necessary to give the same illumination. On the other hand, a single three-lamp unit will be cheaper to make and install than three single-lamp units, and a choice must be made primarily on relative costs.

Another approach is to find the size of the two-or-three-lamp fitting which will give the same light output ratio as a single-lamp unit of a given size. Taking the 8-in. mouth and 60 per cent. relative efficiency single lamp unit as a criterion, it is necessary to increase the mouth of a two-lamp unit to 18-in. for the same efficiency, an increase of size which might make a single two-lamp unit more expensive than two single-lamp units even when installation costs are allowed for. An equally efficient

ARRANGEMENT OF LAMPS.	MOUTH WIDTH	RELATIVE EFFICIENCY
	14¾"	52%
	14¾"	53%
	13⅞"	49%

ABSOLUTE CUT OFF 70°

Fig. 9. Effect of lamp arrangement on light output. Ratio of diffusing trough fitting.

three-lamp unit would be bigger than 22-in., the largest tested in these experiments.

It is possible that the multilamp arrangement with the lamps in the same horizontal plane is not the most efficient. To test this experiments were made with three lamps arranged as shown in Fig. 9. The relative efficiencies quoted are on the same scale as Fig. 8 and the results show the horizontal arrangement to be slightly better than the others. The same result was found for two lamps. In all these tests a cut-off angle of 70 deg. to the downward vertical was maintained.

Other tests made at the same time generally confirmed the conclusions outlined above. A further set of measurements of interest attempted to correlate efficiency with cut-off angle, and Fig. 10 shows the results for a single lamp unit. A change of cut-off angle from 63° to 77° produces a corresponding

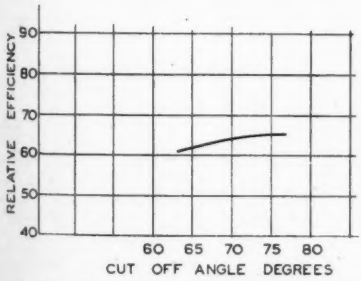


Fig. 10. Effect of cut-off on light output ratio of diffusing trough fitting.

relative efficiency change of only 61 per cent. to 66 per cent. This is much less than is associated with dispersive reflectors for tungsten filament lamps in which a change of 1° in cut-off gives a change of about 1 per cent. in efficiency in the region of 70° cut-off. This is because in the standard dispersive reflector the cut-off is maintained all round the fitting, whereas with the trough fitting the cut-off is measured only at right-angles to the length of the lamp; along the line of the lamp the cut-off is only about 5° below the horizontal measured between one end of the fitting and the opposite end of the lamp, and alters very slowly with change of depth of fitting below the lamp.

(2.1.4) Specular Component of White Enamel.

A factor which affects the performance of enamelled reflectors slightly is the specular reflection from the shiny surface. In addition to reflecting diffusely the enamel has a small specular component (5 per cent.-10 per cent.) of which use can be made. In some designs the reflector contour is made parabolic with the lamp at the focus so that specularly reflected light tends to concentrate beneath the fitting: in other designs the light is spread. The differences are generally not very important, but this property of the reflecting surface does, in part, account for the different contours chosen by different makers.

(2.2) Specular Reflectors.

The important class of fittings using specular reflectors is, as explained previously, restricted during the war, but it is interesting to see to what developments specular reflectors may lead. Glass has already been used to some extent, but probably the most useful material will be aluminium which is light and strong and which with a good anodised surface is durable and can have a reflection factor of the order of 80 per cent.-85 per cent.

Because of the low lamp brightness it is possible to get high intensities only with large fittings. The intensity (candle-power) depends upon the product of the area of the reflector and the brightness to which it can be flashed. Thus for an average lamp brightness B and Projected Reflecting area A the intensity produced will be A x B.

assuming the reflector has 100 per cent. reflection factor and is fully flashed.

If L = Reflector length in inches.
W = „ width in inches, then
A = WL sq. inches.

and if the reflection factor is ρ
the Intensity I = WLBρ in candles, B being measured in candles per sq. inch.

In practice, for trough shaped reflectors, the flashed reflector length will be the same as the lamp length and the intensity from the bare lamp (again the product of brightness and area) is

LBw where w = width (diameter) of lamp.

Thus the ratio of reflector intensity to lamp intensity is

$$\frac{LWB\rho}{LwB} = \frac{W}{w}\rho$$

that is, the ratio of reflector mouth to lamp diameter multiplied by the reflection factor of the reflecting surface.

This assumes that for a length equal to that of the lamp the whole width of reflector is "flashed," i.e., is directing its light to the point of measurement. It ignores the fact that a direct view of the lamp may be seen either in addition to or in place of part of the reflected image, but the calculation is sufficiently accurate for a first approximation.

The bare lamp intensity, measured normal to the lamp length, is about 260 candles and the diameter 1½ in.

Thus a 9-in. wide reflector can give an intensity of

$$\frac{260 \times 9}{1\frac{1}{2}} = 1{,}560$$

candles, assuming 100 per cent. reflection factor, and an 18-in. wide reflector twice this value.

Such intensities, of the order of 2,000-3,000 candles, are, of course, low compared with the values obtainable from quite small tungsten filament lamps in parabolic reflectors, because the brightness of a filament lamp is of the order of 1,000 times as bright as the fluorescent lamp. Thus if the filament brightness of a tungsten lamp is B candles per square inch and the radius of the mouth of a parabolic reflector R inches, the projected area which can be flashed is $A = \pi R^2$ sq. inches, and the maximum intensity when the reflector is fully flashed $I = \pi R^2 \rho B$, where ρ is the reflection factor of the surface.

A 15-volt 100-W. tungsten filament flat grid projector lamp has an effective brightness B of some 1,500 c/sq.cm., and with a mirror reflection factor of 85 per cent. it should be possible in a 12 diameter parabolic reflector to obtain a maximum intensity

$I = \pi \times (6 \times 2.54)^2 \times 0.85 \times 1{,}500$ candles.
$= 930{,}000$ candles.

In practice the mirror would probably not be completely flashed and Fig. 11 shows the flash photograph of an

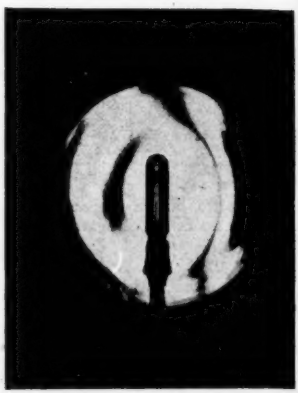


Fig. 11. "Flash" photograph of 1-ft. diameter parabolic reflector and 15-V, 100-W tungsten filament flat-grid projector lamp.

arrangement in which an approximately 60 per cent. flash was obtained. The intensity thus produced would be

$I = 930{,}000 \times 0.6$
$= 560{,}000$ candles.

An intensity of 534,000 candles was measured for this particular set-up, and such values are impossible to achieve with existing fluorescent lamps.

For calculation of illumination from specular reflectors equipped with 5-ft. lamps the lamp or fitting intensity is often not the most useful value to know because the lamp is too long to permit the calculation being based on the inverse square law without making an integration along the length of the lamp. If, however, we know the illumination at various distances from a bare lamp we can use the formula.

$E_F = \frac{W}{w}\rho$. E_L without serious error*

where E_F is the illumination produced by the fitting and E_L is the illumination

* This formula assumes that all parts of the reflector are equidistant from the point of measurement. This is generally sufficiently accurate, but, if not, the fitting may be divided into a number of separate areas and the formula applied to each in turn.

produced by the bare lamp at a given point.

Fig. 12 gives a curve of illumination as a function of distance along an axis normal to the lamp.

The limitation of comparatively low intensity for quite large reflectors is a

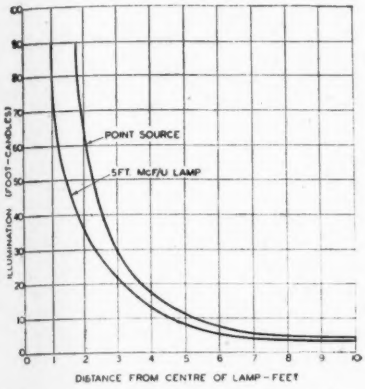


Fig. 12. Relation between illumination and distance for a 5 ft. 80-W fluorescent lamp and a point source of equal intensity.

serious one and makes difficult the application of fluorescent lamps in many spheres for which its qualities of "coolness" and good colour make it very attractive. For example, the hospital operating theatre is a situation for which the lamp would seem ideal. The illumination usually demanded is of the order of 500 ft.c., and the fitting is used about 3 ft. above the working plane. This can be obtained with a 150 G.L.S. tungsten filament lamp in a fitting 3 ft. in diameter which will give a roughly circular patch of light about 1 ft. in diameter with an average illumination of about 500 ft.c. Outside this patch the illumination falls off rapidly although a circular area of 3 ft. diameter is usefully lighted.

The illumination 3 ft. beneath a bare 5-ft. fluorescent lamp is about 20 ft.c., so we require a concentration of 25 lamps or their equivalent, using reflectors to produce the required illumination. If we assume a reflection factor of 100 per cent. the mouth width needs to be 25 x 1½ in., or for a reflection factor of 80 per cent. the mouth width will be

$$\frac{25 \times 1\frac{1}{2}}{0.8} = 46 \text{ in.}$$

assuming the reflector is fully flashed. Its length will be that of the lamp.

Such a fitting with a single lamp would give a strip of light along the operating table and with a single lamp the strip would be too narrow: to get a 1-ft. wide strip would probably need three or four lamps. Thus the straightforward design involves, say, four lamps in a fitting 4 ft. wide by 5 ft. 6 in. long giving a long strip of light as opposed to the 1-ft. diameter patch generally found satisfactory. While not impossible this would need careful design to turn it into a neat and practicable unit and it would consume more than twice the power of the standard fitting (320 watts against 150 watts). In fact, the effectiveness with which the small, bright, tungsten filament lamp can be controlled would outweigh the extra light available from the fluorescent lamps. The fluorescent lamp fitting would have a wider spread of light, but this might not be an advantage since it would result in a high illumination on the coats of the surgeons and nurses which might produce an uncomfortable glare. The colour and diffuse nature of the lighting produced would be excellent, however, from the point of view of the surgeon.

Even more important would be the low radiant heating from the fitting. The surgeon, wearing a protective head covering and a face mask and who may work for several hours continuously under an operating theatre fitting, is very concerned to keep as cool as possible. The radiant heat accompanying tungsten lighting can be reduced by using heat-absorbing glass, but this is not necessary with fluorescent lamps in which the radiant heating is small for quite high illuminations.

Another situation for which 5-ft. lamps would seem ideal is the shop window. The usual intensities are of the order of 100 ft.c. from fittings mounted about 10 ft. above floor level. With tungsten filament lamps this is comparatively easy to do with compact fittings, but with 5-ft. lamps the fittings are very bulky. In practice, because of the comparatively poor light control which can be obtained with fittings of reasonable size, it proves difficult to design an installation more efficient (in terms of foot-candles illumination per watt) than a system of tungsten filament lamps in good silvered glass reflectors.

To obtain 100-ft.c. over the floor of a window 5 ft. deep it is necessary to use about 100 watts per foot width of window; thus, with lamps consuming only 80 watts per 5 ft., six rows of lamps parallel with the glass front are required. Using individual reflectors of 10-in. mouth width for each

row gives a total width of 60 in.: on the orthodox system of ceiling mounting the whole ceiling will then be covered. But this will mean that much of the light will come from the back of the window towards the pedestrian and will light the backs of models: such light is virtually wasted. An alternative is to use fittings each taking two lamps: this reduces the light output. To dispose the fittings in other places than the ceiling is also not easy because of the size of fitting required, and it is reasonable to suppose that those responsible for window design and display will not readily change methods which have proved good unless the new lamps and fittings offer distinct advantages.

These two examples show some of the obvious disadvantages of 5-ft. fluorescent lamps; but there is no reason to assume that the difficulties are insuperable, for as the engineers' skill and experience in handling the lamps increases better answers to the problems may be found, although we cannot alter fundamental physical laws. We may well find, too, that in some fields the quality of the light will compensate for other deficiencies: it may prove, for example, that 100 or 200 ft.c. on the operating table is better liked than 500 ft.c. from tungsten lamps and that 50-ft.c. illumination is sufficient in a shop window because of the more "natural" colour rendering. It should be noted, however, that we generally demand more light and not less from 5-ft. lamps, possibly because the colour is so reminiscent of daylight that we expect the high daylight intensities to which we are used. The answer to such problems we must find by experiment.

Above all, the fittings designer hopes that lamp research will in time overcome the great technical difficulties involved in producing lamps of higher brightness: even an increase of two to one will nearly halve the size of the fittings for many purposes. This will depart from one of the principles which controlled the present lamp, namely, a brightness sufficiently low that the bare lamp is not glaring, but it will help considerably to extend the useful applications of the 5-ft. fluorescent lamp.

(2.3) Spread Reflector Fittings.

Spread reflecting surfaces have not been much used with 5-ft. lamps up to the present time, but may become more popular when anodised aluminium is available again. A large range of finishes varying from pure specular to diffuse can be obtained with this material and doubtless experiments will be made with it. The properties of spread reflectors lie between those of diffuse and specular, and their application will give the designer an opportunity to use his skill. Spread reflectors may have particular value in decorative installations because of the attractive appearance of many of the finishes which can be produced.

(2.4) Prismatic and Diffusing Glass Fittings.

Where prismatic glass is used to concentrate light it suffers from the same disadvantage as a specular reflector—namely, the low lamp brightness. It may, because of its comparative fragility, be of more value in office and decorative lighting than in the factory. For decorative work diffusing glasses will no doubt be widely used, but it must be remembered that the appearance of a glass lit by 5 ft. lamps will generally be different from that with tungsten filament lamps: a wide field of study is open here to the artist and architect as well as the fittings' designer.

(2.5) Plastics.

A number of substitutes for metal have been tried in this country, but so far none has been widely adopted: these substitutes include wood, compressed paper, and various plastics, but they have not been generally adopted, more because of war-time stringency than because of their unsuitability.

The low-operating temperature of 5-ft. lamps makes the use of plastics very likely: in general these materials are not satisfactory at temperatures above 100° C. since they begin to char, and even lower temperatures are desirable with transparent or translucent plastics. Use is being made of such materials in America, where considerable ingenuity is shown in devising special types for fluorescent lighting: for example, louvres have been incorporated in the plastic to control the distribution of light. In one sample the material was 2 mm. thick and the louvres 0.9 mm. apart: both the base material and the louvres can be made in a variety of colours. The louvres run in one direction and are placed parallel to the lamp. Plastic materials can be moulded with prisms and ribs and no doubt many interesting fittings will be designed around them. Their major advantage at present is their light weight, but they have the disadvantage of being soft and scratching rather easily.

(2.6) Louvres.

American practice has made considerable use of louvres to control the light from 5-ft. lamps, more particularly to

shield lamps from the direct view of an observer, and definite shielding angles have been suggested as follows: ([6])

Office lighting:
Lengthwise shielding 30°.
Crosswise shielding 45°.
Store lighting:
Lengthwise shielding 25°.
Crosswise shielding 40°.
Industrial Lighting:—
Lengthwise shielding—none but closed ends are recommended for continuous row installations at low mounting heights.
Crosswise shielding 15°.

(The shielding angle is measured from the horizontal.)

Although these values form an interesting guide they should not be followed slavishly, for we do not always agree with American practice in detail. For example, our tendency in industrial lighting with 5-ft. lamps has been to use a 70° cut-off, which corresponds to 20° crosswise shielding.

The general experience has been small in this country on the use of louvres with 5-ft. lamps, but Fig. 13 shows one installation in which the crosswise cut-off of

Fig. 13. Installation of trough fittings with cross-louvres.

the fittings is 60° (30° shielding angle) and the lengthwise 65° (25° shielding angle). The louvres are white so that the efficiency of the fitting is not greatly reduced, but the louvre brightness is not objectionably high.

(3) Factors in Installation Design.

(3.1) Colour.

The colour of the 5-ft. fluorescent lamp has already been referred to as approximately that of noon sunlight; because of this, the colour rendering of lighted objects is similar to that given by daylight, which most people regard as their standard. Coloured objects seen under 5-ft. lamps have a "freshness" of appearance often lacking under tungsten filament lighting, presumably because of the higher proportion of blue light from the 5-ft. lamp. This is of great value in stores selling coloured fabrics because, not only are the materials seen at their best, but matching of goods can generally be done without going outside the shops; in addition, the colour of the lamps is more constant than daylight.

Five-foot lamps may not be satisfactory, however, for very critical colour-matching in which illuminants should always be judged on their merits for the individual tasks. A certain amount of the light from 5-ft. lamps consists of the mercury line spectrum, so that greens are slightly enhanced relative to other colours, and some blues tend to appear purple. For critical matching there is no better source than the low-pressure carbon-dioxide tube, but since its efficiency is only about 1/10 that of the 5-ft. lamp, this will naturally be used where possible.

A small, but important, application is in chemical analysis where small colour changes or the accurate matching of two colours is often important. 5-ft. lamps are generally satisfactory for such work; occasionally difficulties arise, but they are usually overcome when the operator gains experience.

There is little point, however, in discussing colour-matching at great length while there is only one lamp available. After the war the range of colours will certainly be much increased, and combinations of colours may then be found which will avoid the small defects in the present lamp.

The close approximation to daylight colour makes the 5-ft. lamp valuable for augmenting daylight; this will be discussed later in section 5.

Apart from its colour-rendering properties, however, artificial daylight seems to have considerable psychological value. Possibly this is because we associate a "bluish" light with outdoor conditions and coolness, and yellow and red light (such as tungsten filament light) with interiors and warmth. Certainly, however, very definite opinions have been expressed by many people working under 5-ft. lamps regarding their pleasant colour. It is difficult to disentangle the effect of colour from the other qualities of the lamp which assist in making a good installation, but an interesting point is that many observers find the light a little too "cold" for a sitting room or similar conditions. Opinion is divided on the suitability of the colour for offices: some workers ask if a "warmer" colour is

available, although others find the light "stimulating." Here, again, post-war lamps will probably make it possible to satisfy both users as well as the special needs of restaurants and similar places where colour is of particular importance. Meanwhile, there is ample scope for the form of lamp available at present.

(3.2) RADIANT HEATING.

In all practical light sources the light is accompanied by heat and those working under high illuminations often find the heat very discomforting. Particularly severe examples are the cinema-studio set and the stage where intensities of several hundreds of foot-candles are common, but even in more ordinary walks of life heating due to artificial lighting can be unpleasant: the difficulty is aggravated by the high levels of illumination now recognised as necessary and the long working hours in blacked-out factories so common during the war.

The chief cause of discomfort due to heating of workers is not the total heat produced by the lighting system but the radiant heat accompanying the light. The total heat—determined by the power consumed by the lighting installation—will be dissipated by conduction, convection and radiation. Conduction and convection heat the surrounds and the air; in cold weather control of the heating installation will keep the temperature at a comfortable level; in warm weather suitable ventilation, either through windows or by air-conditioning equipment, should be satisfactory. But radiant heating presents more serious difficulties: the heat accompanies the light intimately, and whatever is lighted is heated. The worker has no way of avoiding the heating unless the lighting is very localised, and reducing the general room temperature will probably result literally in hot heads and cold feet.

In solving this problem with the tungsten filament lamp it is sometimes possible to use heat-absorbing glass which absorbs heat-radiation relatively more than visible radiation. This is the solution often used in hospital operating theatre fittings. But this solution is hardly practicable in a normal industrial installation and the expense, loss of light, and complication, have usually been thought more serious than the heating effect. The 5-ft. lamp is excellent in this respect. The proportion of energy it radiates as heat is about half that from a tungsten filament lamp, and since watt for watt its light output is about double it follows that the radiant heat for a given illumination from 5-ft. lamps is of the order of a quarter that for tungsten filament lamps. The effect of this can only be assessed by working for long periods under tungsten and fluorescent lamps, but the difference at high illumination can be so great that operators have been known to ask whether the fluorescent lamps had a refrigerative effect![7]

(3.3) STROBOSCOPIC EFFECT.

Since electric discharge lamps operating on alternating current were introduced commercially more than ten years ago the possible disadvantages of the periodic variation in intensity have been discussed probably more often than any other quality of these lamps. The chief objection raised is the stroboscopic effect which may be produced when electric-discharge lamps are used to light moving objects: there has also been a suggestion that the varying light has a deleterious effect on the eyes—a suggestion which, if true, would be even more serious. Fortunately this second suggestion has no support either from experiment or from theory. The natural persistence of vision produces comfortably a smooth motion from a cinematograph film exposed at 16 frames per second, and can presumably smooth even more easily light varying at 100 times per second (the number of zero voltage values on a 50-cycle A.C. supply). This is, of course, no proof—the operation of the complex mechanism of the eye cannot be explained in so few words—but expert opinion is, on the whole, satisfied that no harmful effects exist. More important is the fact that electric-discharge lamps in various forms have now had extended use, and we should expect to find good evidence if they produced eye-strain and fatigue: in fact, the evidence is exactly the reverse and comment almost entirely favourable.

The same basis of experience has shown that stroboscopic effects due to moving objects, such as machinery, is much less important than was originally feared. Whenever a doubt exists on the point the obvious course is to have a trial installation, and it is rare for such a trial to reject electric-discharge lamps.

The 5-ft. lamp has a cyclic variation in intensity slightly less than some other lamps (such as the high-pressure mercury vapour lamp), because there is a residual brightness each time the dis-

charge is interrupted due to the phosphorescence of the powder coating. At the same time there is a slight cyclic colour change because the residual light lacks the mercury discharge light which normally forms a part of the total light output: this colour cycle is interesting but of small importance to the lighting engineer.

It is not generally satisfactory to operate 5-ft. lamps on direct current, but two main methods are available to reduce stroboscopic effects. The first is to connect the lamps on separate phases of a three-phase supply: if at any point on the working-plane the light overlaps in equal amounts from each of the phases stroboscopic effects will be eliminated.

Even if only two phases overlap the stroboscopic effect will be small, and this suggests the second method of producing a similar result, which can be used when only a single phase supply is available. For this, two lamps work in a single circuit, one lamp having an inductance as ballast and the other a combination of inductance and capacity: the circuit is so arranged that the lamps operate 120° out of phase with one another, giving the effect of two lamps on a three-phase circuit (8). Fig. 14 shows the circuit arrangements and Figs. 15 and 16 the wave-forms produced by plotting voltage, current, and intensity of light against time (8). The two lamps in this circuit need not be in the same fitting, but, as with lamps connected on separate phases, their light should overlap in roughly equal quantities on the working plane.

A further useful advantage of this circuit arrangement is that the power

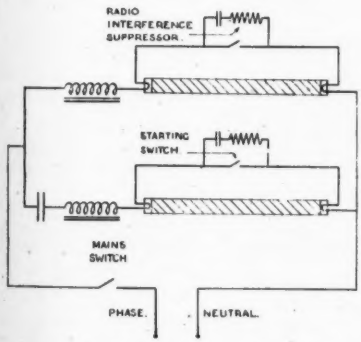


Fig. 14. Circuit giving "two-phase" effect on single phase supply.

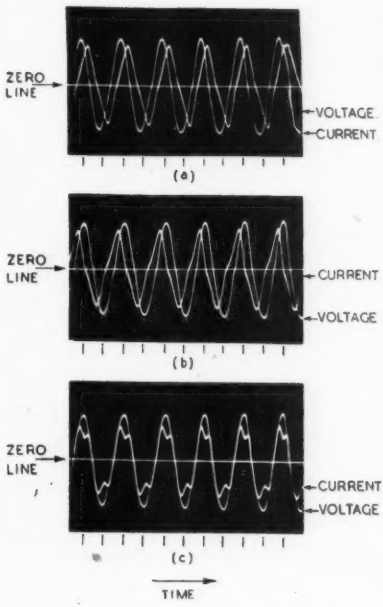


Fig. 15. Variation of mains voltage and current during a cycle.
(Marked time intervals 1/100 second.)
(a) *Inductive circuit.* Current 60° behind voltage. Power factor, 0.5 lagging.
(b) *Capacitative circuit.* Current 60° in advance of voltage. Power factor, 0.5 leading.
(c) *Combined circuit.* Current in phase with voltage. Power factor unity.

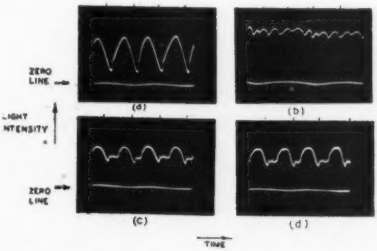


Fig. 16. Variation in light intensity during a cycle.
(Marked time intervals 1/100 second.)
(a) Inductively operated lamps.
(b) Mixed light from these lamps on three-phase supply.
(c) Mixed light from two lamps on combined circuit.
(d) Mixed light from two lamps on two phases.

factor is unity without the use of further condensers. In the normal circuit the addition of power factor correcting condensers is often required: the most usual condenser value is 7.5 mfd. giving an overall power-factor of .8 to .9. To improve this value requires uneconomically large condensers, but an installation can often be cheapened (in initial cost) by group correction of a number of lamps; the most usual number is 3 with a 20 mfd. condenser. The special circuit shown in Fig. 14 has much to commend it, whether or not there is likely to be trouble from stroboscopic effect and the cost is little more than for two lamps operating on the usual circuit if power-factor correction condensers have to be used.

Stroboscopic flicker must not be confused with that due to the cathode glow forming at each end of the tube. This occurs once on each cycle of the alternating supply and thus has half the frequency of the true stroboscopic flicker. The remedy is to cover the electrodes so that they cannot be seen: such covering should be incorporated in the fitting and should not obscure more of the lamp than is necessary. There are other causes of periodic variation in light output from 5 ft. fluorescent lamps (e.g. rectification) but the results are seldom troublesome.

(3.4) Calculation of Illumination.

The light distribution from diffusing trough fittings with 5 ft. lamps is rather different from that of the fittings usually used with tungsten lamps, and also low mounting heights have become common. For these two reasons many designers like to calculate illumination values from iso-foot candle diagrams of the types shown in Figs. 3 and 4. This is a sound method in that it enables an accurate determination to be made of illumination showing variations from point to point of the installation, but it is rather tedious and demands many data; for example, illumination distribution diagrams must be prepared for whatever mounting height is chosen.

Now that a good deal of experience has been gained, however, it is possible to make simple calculations in the same way as is common for tungsten fittings on a basis of a Coefficient of Utilisation which gauges the proportion of the lamp light output which will reach the working plane. The values of the Utilisation Coefficient to be used with the diffusing trough are the same as for open industrial dispersive reflectors for tungsten filament lamps: the lamp lumen output should be taken as 2,400 lumens, which allows for the drop in the first 100 hours of lamp life: the Depreciation factor is taken as 1.43 generally (as for tungsten lamps), but this should be modified for unusual situations. The Room Index which depends only upon the dimensions of the room will be as for tungsten filament lamps.

Thus if we wish to light an interior 40 ft. x 80 ft. to 10 ft.c. service illumination with lamps 10 ft. above working plane we have*

Room index = D

Hence coef. of ut = 0.59,
assuming light walls and ceiling.

Area = 3,200

$$\text{Total lumens} = \frac{\text{Area} \times \text{Illum.} \times 1.43}{\text{Coef. of Ut.}}$$

$$= \frac{3{,}200 \times 10 \times 1.43}{0.59}$$

$$= 74{,}000$$

$$\text{No. of lamps} = \frac{74{,}000}{2{,}400} = 31.$$

Probably the lamps would be mounted 10 ft. apart on a rectangular grid pattern requiring 32 lamps in all. The spacing height ratio would then be 1:1 which should give a satisfactorily diffused light.

A similar calculation can be applied to fittings with two lamps, but the coefficient of utilisation should be reduced by 10 per cent. to allow for the lower fitting efficiency. The differences between good fittings of different makers are no greater than for those with tungsten lamps.

It should be remembered that this calculation is not intended for use with specular reflectors, or with diffusing reflectors mounted below say 5 ft. above the working plane since the illumination will probably be too patchy to make a calculation of average illumination of any significance: here direct use should be made of iso-foot-candle diagrams.

With diffusing troughs mounted more than 5 ft. above the working plane the light distribution is sufficiently symmetrical (about a vertical axis) to use the same rules for spacing height ratio as with tungsten dispersive reflectors, namely 1.5 to 1 as the maximum and 1 to 1 as a desirable spacing height ratio.

(4) Present Applications of 5 ft. Fluorescent Lamps.

(4.1) Factory and Workshop Lighting.

The most important application of 5-ft. lamps during the war is, naturally,

* Data taken from Electric Illumination Handbook No. 2 (Illumination Design Data).

to factories to aid the effort to increase production. The availability of large diffusing troughs has led to a form of lighting not frequently encountered in tungsten lighting installations. In this method, often called "localized" or "localized-general" lighting, each definite working area has its own lighting system. Generally this results in each bench, and often each worker, having an individual fitting. Common good practice with tungsten lighting is to provide an illumination of 6-10 ft.c. over the whole factory floor area and to combine this with local lighting giving 50-100 ft.c. over a small part of the work. With 5-ft. lamps some 30-50 ft.c. illumination is provided over the whole area of work, and gangways and spaces between benches and machines are not so well lighted. Fittings are mounted only a few feet above the work so that advantage is taken of fitting size to reduce shadows, and thus give a soft appearance to the lighting: coming over a wide range of angles the light has a chance to "get-round" small obstructions in the work. This is of particular value for such tasks as radio set assemblies.

The low brightness of the lamp is of great value for this low mounting because the glare effect is comparatively small both for direct light and reflections in shiny surfaces; the low brightness of the fluorescent lamp often gives much easier seeing conditions on polished surfaces than does local tungsten lighting. However, it is still very important to shield the lamp from the worker's eyes (in their normal working position) as far as possible. A sustained view of the bare lamp is undesirable. Often, even now, far too little importance is attached to avoiding glare, particularly reflected glare.

Psychological points also are of much greater importance than many people imagine. As an example, in a factory lit with local fittings the upper parts of the walls, and the ceilings, tend to be dark and so give an unpleasant tunnel effect which is depressing to the workers. This can be avoided in two ways, (1) by using special fittings to light the roof and walls, and (2) by using trough fittings with gaps at the tops so that some light escapes upwards. Either method can be satisfactory.

This treatment has a physiological basis in that if workers are continually looking from a well-lighted bench to a dark background, their eyes are in a continual process of adapting from one brightness level to another: in excess, this tends to produce eye-strain and fatigue, and lighting the background overcomes the difficulty. However, the psychological effect is probably more important: the gloom due to unlighted upper walls and ceilings gives a sense of oppression, and when these are lighted workers find this "takes a weight off their head."

Such practice may be regarded as wasteful and certainly it is not easy to prove it economically sound. But there is no doubt of the effect on most workers, and, in general, production is better when the workers are happy.

Good use can also be made of bright and cheerful coloured paints in workshops and factories. Not only can the walls have something better than whitewash, but girders, doors, etc., should be painted much more attractively than is common at present. Machinery, too, may well be painted in something other than the standard grey. Some experimenters have pointed out the resulting increased ease of seeing because of the better contrasts between work and material. When decorating a room the floor, also, should be kept light if possible: this helps materially to improve the general appearance as well as lighting, to some extent, the undersides of machines.

It is important to remember the shadows cast by fluorescent lamp fittings when laying out an installation. Although the source is long it is relatively narrow and although it casts little shadow for objects at right angles to its length, it may cast heavy shadows from objects on its axis or of long straight objects parallel with its axis. In practice if lamps in diffusing fittings are mounted only at 2-3 ft. above the working plane the size of the fitting is generally sufficient to make shadows

Fig. 17. Fittings at low mounting-height for fine assembly work.

soft: if the fittings are 8 ft. or more above the working plane any part of the work will receive light from several fittings so that again the shadow effect is unimportant. Between these regions of 3-ft. and 8-ft. mounting height above the working plane, it is thought desirable to stagger the reflectors placing them along and across the bench (9).

Although low mounting of 5-ft. lamps in diffusing reflectors is the most usual method, a large range of mounting heights is being used, and Figs. 17-20 show some installations. A considerable diversity of mounting heights will be seen; sometimes the reflector is below the workers' eyes, and sometimes close to the ceiling. Generally, the fittings run along the length of the bench, placed over the workers' heads or slightly behind them, and there is little doubt that such an arrangement will generally provide satisfactory lighting.

Fig. 18. Fittings at medium mounting-height in chemistry laboratory.

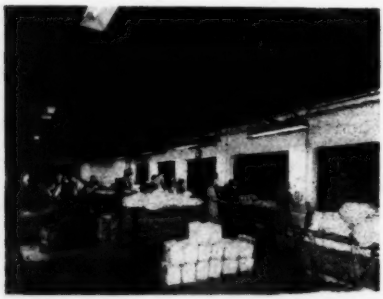


Fig. 19. Fittings at high mounting-height for general lighting of packing department.

Fig. 20. Installation of continuous trough fittings.

(4.2) OFFICES.

In factories it is generally necessary to use fittings round lamps because the reflectivity of walls and ceilings is too low to make efficient use of light falling on them. In offices and similar rooms, however, the decorations can be kept in good condition, and here installations of bare lamps have been used.

Where the lamps are mounted reasonably high (say, 10 to 12 ft. above the working plane), the results can be good, particularly as the ceilings and walls are well lighted and provide, therefore, a secondary source of large area and low brightness making shadows very soft. But care must be taken in recommending such an installation to be sure that the lamps will not be glaring. Generally speaking, in large rooms it will pay to shield the lamps from direct view with diffusing glass or louvres. If bare lamps are used it should be remembered that an end-on view of the lamp is less glaring than a sideways view.

Fig. 21 shows a drawing office installation for which 5-ft. lamps are particularly valuable in giving freedom from shadows in a properly designed installation. In such an office the artificial lighting should be arranged bearing in mind the natural (day) lighting of the office.

Fig. 21. Drawing office installation.

Many draughtsmen prefer the light to come from their left hand, and generally their draughting boards are arranged to receive the kind of natural lighting which they like. There is much to be said for arranging the artificial lighting system as far as possible, to give the same lighting by night as by day—assuming that the day lighting is good.

In offices, as in workshops, good lighting and pleasant decorations will add to the efficiency of the staff.

(5) Fluorescent Lighting in the Future.

The temptation to consider the future development and influence of fluorescent lighting can hardly be resisted; the possible lamp developments and the range of applications are so considerable that he would be an unusual engineer who did not at some time turn his thoughts to what may come. In doing this we should not think only of the 5-ft. lamp or even of low-voltage lamps, for there is every reason to believe that when manufacturing facilities are again available the high-voltage lamp, which developed so rapidly before the war, will come into its own once again. This is the trend in America, where the success of low-voltage fluorescent lamps has stimulated interest in the high-voltage types which are now used more and more. One feature of the high-voltage lamp for which no counterpart at present exists with low voltages is a luminescent material activated by a neon discharge. Lamps of this kind, developed in this country and widely used before the war, have a life many times that of mercury-discharge lamps. The neon-filled lamps did not give a "white" light, but development was in its infancy and must go much further. Apart from this advantage, however, the long lamp (the standard length of high-voltage tube was 8 ft. 6 in.) has an obvious appeal where continuous lines of light are required: there is little point in joining two short lamps end to end where one long lamp will do.

The recent tendency is towards continuous lines of lamps mounted close to the ceiling, and this certainly gives a pleasant looking installation. In America this has led to a wide use of louvres in many forms, such as an "egg-crate" formation, which will doubtless be tried in this country. But this tendency is only a step in the direction of built-in-lighting—lighting, so to say, "tailored" to the job. This trend of development would have come about in any event; but there is no doubt that the advent of fluorescent lighting has given an impetus to the movement just as it has made us think more deeply of the psychological value of lighting, including the importance of decoration. For "tailor-made" installations the high-voltage lamps are excellent because they can be made to suit the design rather than suiting the design to the available lamps.

Possible application of fluorescent lamps are many: shop-window lighting, photography, the theatre, hospitals and public buildings, factories, and even street lighting will doubtless feel their influence; but perhaps the most interesting speculation of all is their possible effect on building and architecture.

At present, building design is governed largely by fenestration. Most people regard adequate daylight as an essential part of a good building and the architects' designs have to take account of this. The design depends very much on ensuring that every room has ample daylight, and window shapes and positions are thus controlled.

Fluorescent "daylight," which blends almost perfectly with true daylight, may serve not only to improve the lighting in existing rooms which have insufficient daylight, but also to give the architect a greater freedom than he had previously in his building design. To take a simple example: to obtain the best daylight in a room requires a high window reaching, preferably, to the ceiling; to obtain a good view requires a low window reaching, possibly, down to the floor. In the Georgian style of English building this fact was recognised and windows were tall and comparatively narrow with excellent results both in appearance and in the lighting obtained (Fig. 22).

In architecture, however, as in all

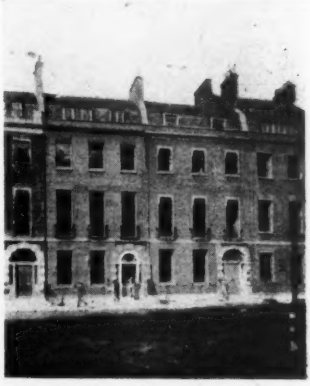


Fig. 22. Georgian style buildings.

forms of art, fashion has an important effect on design and the modern tendency is towards strongly marked horizontal lines. This tendency is not easily compatible with the Georgian type of window, but leads rather to low, wide windows which cannot give the best view and the best light (Fig. 23). Here is a conflict between scientific principles and aesthetic demands which fluorescent lighting may help to resolve. We generally value a window more for the link it makes with the outside world by the view it gives, than for the light it admits: if the windows are placed so as to give a good view and artificial light is used to supplement the daylight, and if the combination of artificial and natural light is well contrived, it should be possible to get satisfactory results. We tend to be prejudiced against such an arrangement because artificial light never seems a satisfactory substitute for daylight; but that is because we have not had suitable artificial light sources and because the problem has not been studied sufficiently.

The artificial light will have to be paid for, but this will be offset, to some extent, by a saving in fuel for heating which, particularly in cold places, may be considerable. Heat is lost through glass at the rate of 1 B.Th.U. per hour per square foot of glass for 1 Fahrenheit degree difference in temperature. 1 B.Th U. per hour is equivalent to 0.293 watts, so that, for example, 100 square feet of window area with a room temperature of 65° F. and an exterior temperature of 40° F, will transmit heat at a rate of

$$100 \times (65-40) \times 0.293 = 735 \text{ watts.}$$

The overall difference in cost involves many factors, including installation as well as running costs, but it is evident that the saving in heating due to a reduction in window size cannot be ignored.

Another example of the possible use of artificial light as a supplement to daylight is found in buildings having balconies. In flats, particularly, occupants and designers like balconies (Fig. 24); but they have the serious disadvantage of overshadowing the rooms below and of reducing materially the natural lighting. Again there is a conflict: if we want balconies we must sacrifice light, and if the balconies are large the sacrifice will be considerable. If fluorescent lamps enable us to have good balconies and good light they will be of great value.

Even the problems of town-planning may be affected by fluorescent lighting. If we state a requirement for the minimum daylight which shall enter a room we can calculate desirable building shapes [11], [12]. Such calculations are based on the total floor area required and the area of ground available, and are aimed at minimising the mutual obstruction between neighbouring buildings: this mutual obstruction is the most serious single drawback to obtaining

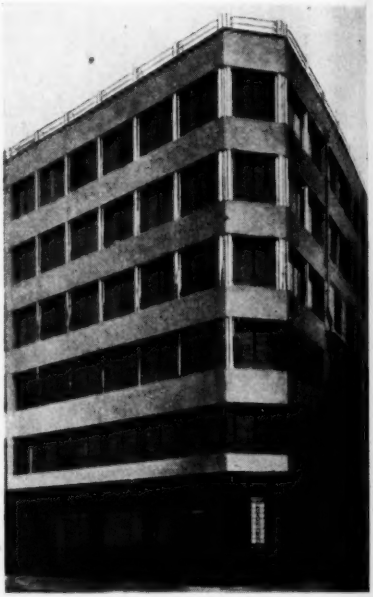


Fig. 23. Modern building with strong horizontal lines.

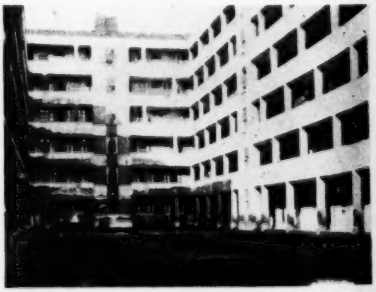


Fig. 24. Modern block of flats showing balconies.

good daylight in buildings in densely populated areas. The results suggest that Y-shaped and cruciform plans (among others) are good and that hollow squares are poor, particularly when the square is so small as to become a light-well. Nevertheless, for some types of buildings (such as hospitals), the rooms facing the square or light-well have the great advantage of quiet and are, therefore, very desirable; if artificial light can make up the deficiency in daylight, full advantage can be taken of this type of building.

In heavily built-up areas even the best planning will not provide adequate daylight for all parts of all rooms unless the ground area is severely restricted. In such circumstances, where land values are high, it may be economically sound to pay for artificial daylight rather than restrict the accommodation available, provided that this can be done without the occupants suffering.

This should not be taken to mean that the natural lighting of buildings can be forgotten or that the building of the future will be windowless (although some experiments on these lines have been made). Daylight is free, and it will be a bad design which does not make the best use of it; but architects who master the art of combining natural and artificial light will have a wider scope than in the past, and it is the duty of lighting engineers to help make good use of this wider scope. Work is required to establish the basic principles of mixing artificial and natural light, and answers are needed to such questions as "What illumination should be provided with artificial light, and how is illumination related to the daylight factor?" "How should this light be distributed, and what is the best colour?" When the answers are known, lighting engineers and architects must learn to appreciate each other's point of view in order to make good use of the knowledge.

Lighting engineers have a great duty to the community; they must be continually trying new ideas and thinking on new lines. Let us not laugh at the man who proposes to control his light so that it has a warm colour on a cold day and a cool colour on a warm day—a perfectly feasible proposition with fluorescent lamps—however peculiar it sounds. In the past we have paid so much attention to quantity of light as the most important factor that we have tended to forget the many other aspects of a good lighting installation. We should remember that good lighting promotes happiness as well as efficiency: happiness is the right of everybody, and to this end we should make the best use of modern lighting equipment.

(6) References.

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(8) Osram T. T. Circuit. Osram Bulletin, Vo. 20, No. 3, October, 1942.

(9) Lighting Layouts and Economy. M. W. Pierce. Osram Bulletin, Vol. 20, No. 2, July, 1942.

(10) Planning for Daylight. J. W. T. Walsh. Trans. I.E.S. (Lond.), Vol. 7, No. 2, February, 1942.

(11) Population Densities and the Heights for Buildings. H. E. Beckett. Trans. I.E.S. (Lond.), Vol. 7, No. 7, July, 1942.

(12) Daylighting of Buildings in Urban Districts. W. Allen. Journal of the R.I.B.A., Vol. 50, No. 4, February, 1943.

Fluorescent Lighting Manual, by C. L. Amick (McGraw-Hill Book Company, Inc.) gives a comprehensive survey of present American practice in using low-pressure fluorescent lamps.

DISCUSSION

Dr. S. ENGLISH, who opened the discussion and moved a vote of thanks to the author, said that as one who had come up against many of the little difficulties mentioned by the author, he felt that the paper had either answered some of his problems or given a clear indication that the answers would be forthcoming in the near future. There were, however, a few matters he would like to know more about. For instance, there was the question of colour. Many people did not like the greenish colour of present-day fluourescent lamps. Should we,

in the post-war period, have lamps with a more pleasing colour? His own work in connection with these lamps had been in providing fittings for a Government Department which wanted very precise light control on a certain limited area—diffusing reflectors were therefore out of the question. He had had to go to specular reflectors and could confirm all that the author had said with regard to these. His own experience also confirmed that in working with tubular lamps polar curves were useful only within certain very narrow limits, and he had found it necessary to rely not upon these curves but on actual illumination values determined at the height at which the lamps were to be used. At very low mounting heights the illumination from these lamps was along a rectangle, and the higher the lamps were raised the broader the rectangle became, till at a height of about 10 ft. the distribution would be chiefly at right angles to the length of the trough. Polar curves were therefore of very limited use, as the shape of the lighted area changed as he heighth of the lamp was increased. The author had mentioned the possibility of lamps coming along which would be 2, 10, or even 20 times as bright as the present lamps. What hopes were there of that? If such lamps did appear, he would be much happier than he is at present. As regards the use of plastics for lamp fittings, he believed they had been used on a large scale in America, but a difficulty had been encountered in that many plastic materials had a nasty habit of developing a static charge which caused a great deal of dirt to settle on the fittings. Indeed, the dirt was literally attracted to them and stuck. Was there any information with regard to that, and, more important still, was it possible to prevent the development of a static charge on these materials by some form of surface treatment that did not spoil them from the illuminating point of view?

Mr. R. Maxted, remarking that the paper contained an excellent collection of data, said it was high time the Society had a paper on fluorescent lighting. However, he joined issue with the author on various technical matters. For instance, the complex problem of reflector efficiency was over-simplified in the author's curves relating efficiency and width of reflector. The overall efficiency quoted is based not only on the optical efficiency of reflector but also on the reduced output of the source at the higher ambient air temperatures in the fitting. Overall efficiency is therefore a function of both optical and thermal design, and he could not agree that the unqualified width dimension exerted an over-riding control of either. His experience of commercial reflectors had shown a 7-in. reflector to have a higher optical efficiency than a 10-in. reflector. Reflector profile had an important effect on efficiency, even with semi-diffuse reflectors, as those with experience of designing for earlier sources would agree. Nor was thermal design linked fundamentally with reflector width, as the high efficiency of open-top reflectors demonstrated. Closed reflectors were likely to become important, and it should be possible to design lamps and circuits to give nominal lamp watts and the declared lamp output at temperatures encountered in such fittings.

Referring to the use of fluorescent lamps in operating theatres, his experience did not confirm the difficulties envisaged by the author. Apart from increased comfort for the surgeon, the decreased radiant heat was very important to the health of the sensitive tissue exposed. The usual concentrating filament lamp design was inferior in regard to heat and shadows, and all experience of fluorescent lighting taught that "foot-candles per watt" provided a very inadequate measure of merit.

Regarding the reference to his own investigations of factory lighting early in the war, he would confirm that the "refrigerative effect" mentioned by operatives was due to the psychological effect of introducing into hot factories the daylight colour and quality normally associated with outdoor conditions. He had never found stroboscopic effect taken seriously by workers, but this could be entirely eliminated by high-frequency (500-cycle) supplies which also had economic advantages.

Turning to installation design, Mr. Maxted agreed that the overhead installation looked neater, but said there were inherent advantages in the use of low-mounted open-top reflectors. If placed to conceal the lamp, these reflectors gave a high illumination of the working plane and the upward light illuminated walls and ceilings at a somewhat lower level. With light-coloured walls and ceilings, the balance of brightness thus obtained was most attractive and seems to be fundamentally correct. Thus the eyes went normally to the higher brightnesses which were at the work bench and not the ceiling. The lower brightness of walls and ceiling gave a valuable impression of spaciousness.

Econonmically, the low-mounted open-top unit was an obvious choice in wartime. The same visual result might be obtained with louvred ceiling units when

we could afford to pay for appearance in peace time. With limited supplies of equipment, the choice was often between good appearance and effective lighting. Surely from the fluorescent lamp in particular we had learnt to consider first the purpose of lighting and to design on a functional basis. Lighting was first a matter of providing the best visibility for efficient working and secondly a plant problem.

Dr. J. W. T. WALSH said there were circumstances in which he felt the fluorescent lamp was better without a fitting than with one. He asked the author whether he agreed that, when it was possible to get these lamps for domestic lighting, if there were white ceilings and light decorations the light distribution might be very good if the bare lamps were mounted about a foot from the ceilings, provided, of course, that the ceiling was not too low.

With regard to the stroboscopic effect, would it be possible to incorporate a material with a much stronger phosphorescent effect, the result being to smooth out the ripples in the fluorescent light?

Mr. C. M. PHILLIPS expressed disappointment that the author had not had more time to deal with the fittings side. Going through the Proceedings of the American Illuminating Engineering Society he noticed that over a period of three years there had been several papers on these fittings. One of these papers had attempted to set down a specification, and it placed appearance last but one in order. Had we in this country concentrated more on appearance to the detriment of the other factors, such as location of the accessories and efficiency of performance? Perhaps with more time the author might have touched upon optical efficiency and performance efficiency. This was the first lamp in which temperature was a very important item in the actual efficiency of the reflector. He had seen cases where the purely optical efficiency of the reflector had been well over 70 per cent., but the useful efficiency was nearer 60 per cent. He could well imagine that if the thermal side of reflector design was not emphasised, designers might try to improve optical efficiency where all the time it was the thermal efficiency that needed to be taken into account.

With regard to polar curves, they served a very useful purpose in the laboratory in determining the efficiency of a fitting. It was obviously desirable to have a fairly long throw with a larger source, and it had been found that round about 16-ft. throw the discrepancy was not very large, and at 20-ft. the discrepancy was almost negligible. It would be interesting to know, however, what happened to the temperature of the fitting or the thermal distribution when the lamp was mounted on end. Obviously it was much easier to have a photometric set-up where the throw was vertical.

He rather felt that we might change right over in our use of specular and diffused reflectors in future. At very low mounting heights it might be desirable to have a specular reflector and the diffused reflector at high mounting heights.

Mr. A. CUNNINGTON, speaking on the psychological aspect, referred to some experience in certain underground train-control rooms, which were in the nature of air-raid shelters, where work was carried on for twenty-four hours a day. Before fluorescent lamps were installed there existed very nicely diffused tungsten installations which gave a great deal of satisfaction to the staff. When the fluorescent lamp installation was put in, the daylight effect pleased the staff at first, but after a time, possibly due to the monotony, it was found that the staff swiched over to the tungsten lighting. He thought it was done to get a little variety. If we were to have artificial daylight in building construction in the future, we should not have to be content with just putting in fluorescent tubes, because of the necessity for variety. Something could be learned from stage effects, in which sometimes there was a vivid impression of the sun shining through a window. An application of this form of artificial sunlight had been seriously thought of in an underground telephone room where the operators complained of monotony, but it had not actually been carried out, mainly on account of cost. In reply to Dr. Walsh, he had dealt with installations in which bare tubes had to be used and the ceiling was made use of as a back reflector, the ceiling being exceptionally low.

Mr. P. J. WALDRAM entered an energetic protest against the somewhat half-hearted advocacy by the author of the windowless building, which he regarded as a psychological and physiological horror. Such buildings had been advocated because of the equable temperature and steady lighting which could be obtained artificially in them; but our bodies and our eyes had been developed

over millions of years to cope with Nature's variations of temperature and light, and when the necessity for that exercise was removed, then our visual and bodily health suffered. He had been assured before the war by a most eminent physician that the workers, both manual and sedentary, in American windowless factories suffered seriously from uncontrollable afternoon somnolence. The report of the Chief Inspector of Factories just published drew attention to the greater output under natural lighting. Fluorescent lamps had so many fields of useful application that it would be a pity to advocate them in a way which might render them unpopular.

Mr. J. M. WALDRAM said he did not think the author had really intended to carry his advocacy of the fluorescent lamp to the point of putting forward the windowless building. In cities, however, the great majority of rooms were necessarily side-lit and suffered serious obstruction from buildings opposite to them, so that despite all efforts of the architect they were necessarily inadequately lighted at the rear. Fluorescent lamps used to reinforce daylight in these parts of naturally lighted rooms would make greater areas of rooms useful and so increase materially the useful accommodation of a building. He drew a comparison with the effect of central heating in increasing the accommodation of a house in winter, by making all rooms habitable all over.

Mr. R. W. STEVENS expressed the view that when fluorescent lighting was applied, as it was hoped it would be after the war, many of the objections to it now on the score of colour and stroboscopic effects would disappear. It would be possible after the war to have decorations which would make the best use of fluorescent lighting, whereas now fluorescent lighting installations were put in to replace tungsten installations with the type of decoration most suitable for the latter.

Mr. J. S. Dow, referring to the possible use of these lamps outdoors, said he had been told that even indoors in very frosty weather they were inclined to "jib" a bit. For the lighting of narrow streets and for signs, exhibition boards, and notices they should have applications, unless there were other drawbacks. He rather felt that Mr. J. M. Waldram, in his address to the Conference of the Association of Public Lighting Engineers recently, was a little harsh in suggesting that these lamps had little application for public lighting. For ordinary traffic routes and on open roads, perhaps, that might be so, but if we discarded the idea that the lamps had to be slung on every lamp-post, and appreciated that they could be attached to the sides of buildings, they might serve a very useful function in city streets, more especially in shopping centres.

The CHAIRMAN (Mr. R. O. Ackerley), commenting on the suggestion by the author that we should not always follow American practice, asked whether it was not true that the American lamps in general were slightly brighter than the present English lamp, and therefore it was necessary to have the louvres that had been described. He thought the suggestion made by Dr. English, that it was necessary to take illumination readings at the particular levels at which these lamps were used, was now generally adopted. The E.L.M.A. had published a leaflet on the subject which people designing fluorescent lamp installations would find useful. Mr. Ackerley supported what Mr. J. M. Waldram had said with regard to the use of fluorescent lamps to supplement natural daylight in rooms where there was obstruction to the entry of natural daylight, and mentioned one instance in which this had been very effective.

Mr. W. R. STEVENS, replying to the discussion, said he expected that fluorescent lamps with different colours would be available after the war, but he could not say whether we would find them more pleasing colours. In America there were two or three lamps having a "near white" colour, but for some work these were not altogether satisfactory, and sometimes a mixture of lamps of different colours was used to get the required effect. He agreed with Dr. English with regard to the necessity for taking measurements at the particular mounting height involved, especially with low mounting heights: at the same time, for high mounting heights the usual method of calculation of illumination was satisfactory. As to getting lamps with 2, 10 or even 20 times the brightness of the present lamps, he thought twice the present brightness was a possibility, but the 10 or 20 was, perhaps, rather a wild hope. He did not know the remedy for the effect of the static charge on some plastics, and he did not believe that plastics would sweep glass from the lighting field. That had been suggested many times

before the war, but in his view it would be a long time before it happened.

He agreed with Mr. Maxted that profile had some bearing on light output ratio of diffusing fittings and a bad profile would cause loss of light. The "shadowless" quality of the light from fittings for operating theatres depended on the size of the fitting. The bigger the fitting the better it could be, and there might be attendant advantages in regard to colour and low radiant heating which would favour a fitting using fluorescent lamps. Mr. Maxted had made an important point in desiring low mounting fittings because they have good distribution of light and brightness on the work, and not so high a brightness overhead.

Whilst agreeing with Dr. Walsh that bare lamps in the right circumstances could be attractive, it should be noted that American practice was moving away from bare lamps. He did not know what possibilities there were of increasing the phosphorescent component for obviating the stroboscopic effect.

The importance to be attached to appearance, mentioned by Mr. Phillips, depended on the type of installation. Appearance was not so important in a factory as in the home. With regard to polar curves, he was not sure whether 16 ft. was sufficiently far away for polar curves. He did not think it should make the method inaccurate to place the lamp on end, and the work of Mr. Maxted in this connection had indicated that that would not be the case.

In reply to Mr. P. J. Waldram he said he did not advocate windowless buildings. Indeed, he did not necessarily advocate using fluorescent lamps instead of daylight, but they could be a great deal of help to the architect, and it was the duty of the illuminating engineer to give the architect all possible assistance. It was in the sense of using fluorescent lighting to back up natural lighting, as mentioned by Mr. J. M. Waldram, that he had discussed this matter.

Whilst, as Mr. Dow had said, fluorescent lamps sometimes "jibbed" even indoors when switched on, he felt sure that that difficulty would be overcome in the future. He did not think Mr. Waldram, Jun., in his address to the A.P.L.E. Conference, turned down the fluorescent lamp entirely for street lighting. It was stated that they were not obviously application for arterial roads; he did not think Mr. Waldram would condemn them generally for application in the streets.

As to the Chairman's suggestion that louvres were necessary with American lamps because they were a little brighter than ours, he did not think the small extra brightness was sufficient to force the use of louvres. It was just a fashion in a country in which designers had had more time and opportunity to experiment than we had. Doubtless we should eventually stabilise the basis on which we should use louvres.

I.E.S. Fellowship

The following applications for Fellowship have been accepted by the Council:—

Harris, J. B.
Hubble, L. H.
Hunt, R. W.
Pelerin, R.
Souter, W. T. F.
Turner, H. J. A.
Vine, W. J.

The Illuminating Engineering Society is not, as a body, responsible for the opinions expressed by individual authors or speakers.

With a view to avoiding possible confusion with other publications, reference to these Transactions should be in the form:—"Trans. Illum. Eng. Soc. (London)."

Forthcoming Sessional Meetings

1943.

Dec. 14th. Discussion to be opened by Dr. S. English and Mr. R. Maxted on **Street Lighting Specifications of the Future; Should They be Based on the Design of the Unit or the Effect of Illumination?** *(Joint meeting with the Association of Public Lighting Engineers, to be held at the Institution of Mechanical Engineers, Storey's Gate, St. James's Park, London, S.W.1.)* **5 p.m.**

1944.

Jan. 18th. Addresses on **The Place of Science in the Art of Lighting,** by Mr. Allister MacDonald, F.R.I.B.A. (Chairman, Architectural Science Board), and Mr. R. O. Ackerley, F.I.E.S. (The chair will be taken by Mr. Percy Thomas, President, R.I.B.A.) *(Joint Meeting with the Royal Institute of British Architects, to be held at the R.I.B.A., 66, Portland Place, London, W.1.)* **5.30 p.m.**

Sessional Meetings in London

Fittings for Fluorescent Lamps*

The opening meeting of the session was held in the Lecture Theatre of the E.L.M.A. Lighting Service Bureau, 2, Savoy Hill, London, W.C.2, at 5 p.m., on Tuesday, October 12, 1943. In the absence of the President (Dr. H. Buckley), Mr. Ackerley presided.

In opening the proceedings Mr. Ackerley explained that the President was absent on a special mission, and accordingly it had been found necessary to postpone the Presidential Address, usually delivered at the opening meeting of the session. The evening had been allotted to a paper by Mr. W. R. Stevens.

Proceeding, Mr. Ackerley recalled that one of the events at the opening meeting was the presentation of the Leon Gaster Memorial Premium to the author of the best paper read before the Society during the past session. The Council had unanimously decided to award the premium to Mr. H. C. Weston for his paper, entitled "Proposals for a New Lighting Code," read before the Society on January 12, 1943.

The award having been presented to Mr. Weston, amidst applause, a paper, entitled "The Design and Application of Fittings for Fluorescent Lamps," was read by Mr. W. R. Stevens. The paper was illustrated by numerous lantern slides and demonstrations and gave rise to a good discussion, in which the following took part: Dr. S. English, Mr. R. Maxted, Dr. J. W. T. Walsh, Mr. C. W. M. Phillips, Mr. A. Cunnington, Mr. P. J. Waldram, Mr. J. M. Waldram, Mr. R. W. Stevens, Mr. J. S. Dow, and Mr. R. O. Ackerley.

After Mr. Stevens had briefly replied to the discussion, a vote of thanks to the author and to the E.L.M.A. Lighting Service Bureau for their hospitality terminated the proceedings.

* This paper and the ensuing discussion appears in full on pp. 175-194.

The Lighting of Public Buildings

The second meeting of the session was likewise held in the Lecture Theatre of the E.L.M.A Lighting Service Bureau, and took place at 5 p.m., on Tuesday, November 9.

The President (Dr. H. Buckley) presided for the first time since his election and was introduced by Mr. R. O. Ackerley, to whom a cordial vote of thanks for his services during the past session—especially in connection with the study of post-war problems—was passed with acclamation.

Mr. Ackerley, in a brief acknowledgment, expressed his appreciation of the help which he had received from all sections of the Society.

Mr. W. T. F. Souter was then called upon to read his paper, entitled "The Lighting of Public Buildings," which, it was explained, originated partly in the work carried out by one of the committees concerned with Post-war

The Library

It will be recalled that the original list of books in the Library appeared in the Transactions for April, 1939, and that certain additions have since been recorded.

The following further additions have since been made:

Section No.	Title	Author	Date	Presented by
1/25 B	The Science of Illumination ...	Dr. I. Bloch	1912	Mr. E. W. Murray
1/56	Reading as a Visual Task ...	Dr. M. Luckiesh and Frank K. Moss ...	1942	Mr. J. S. Dow
2/11	Modern Industrial Lighting ...	G. Bernard Hughes ...	1943	Mr. J. S. Dow
19/13	Bunsen's Gasometry	Robert Bunsen ...	1857	Mr. S. H. B. Langlands
11/16	Fluorescent Lighting Manual	C. L. Amick	1942	Philips Lamps, Ltd.
23/25	The Place of Glass in Building	John Gloag	1943	Dr. W. M. Hampton

Members are reminded that the Library at 32, Victoria Street may be inspected by appointment and that copies of most books can be borrowed by post, under specified conditions.

Lighting Reconstruction. The paper reviewed various aspects of the subjects, schools and libraries, picture galleries and museums, hospitals, town halls, etc., being discussed successively by the aid of lantern slides of installations.

In the ensuing discussion Mr. C. W. M. Phillips made some reference to American practice, more especially in connection with school lighting, and this subject was touched upon by Mr. P. V. Burnett, Mr. F. C. Smith, and others. After further contributions had been made by Mr. Geo. Smith, Mr. E. Stroud, Mr. R. O. Ackerley, and Mr. L. G. Applebee, a reply by Mr. Souter, followed by the usual vote of thanks to the author and the Bureau, terminated the proceedings.

Papers Read Before Centres and Groups

DIFFUSING GLASSWARE. By DR. S. ENGLISH (FELLOW).

*Summary of an Address delivered before the Birmingham Centre on March 26, 1943, and the Leicester Group on April 6, 1943.**

The characteristics of the three types of diffusing glass were discussed and the mechanism of the diffusing process analysed in each case. Reference was also made to the work done on that subject by the B.S.I. Committee, the International Illumination Commission, the Technical Committee of the I.E.S., and several independent research workers. As a result of this work much data had been accumulated concerning the types of diffusion, i.e., polar curves of brightness given by each of the three types of diffusing glass, but so far the main aim of the Society's Technical Committee, namely, the predetermination in a simple manner of the surface brightness and lumen output ratio of lighting fittings made of diffusing glassware had not been achieved.

A method of predetermining these performance figures for fittings made of completely diffusing opal glass based on the use of easily determinable characteristics was presented. From the direct transmission factor, $T_{(dir)}$, and direct reflection factor, $R_{(dir)}$, of completely diffusing opal glass plates, the surface brightness of both sides could be calculated when one side was illuminated by a lamp of known strength at a measured distance from the plate and normal to it.

Surface brightness on side facing source in c/sq. inch

$$= \frac{\text{C.P. of lamp}}{d^2} \times \frac{R_{(dir)}}{144\pi} \text{ c/sq. in.}$$

Surface brightness on side away from source in c/sq. inch

$$= \frac{\text{C.P. of lamp}}{d^2} \times \frac{T_{(dir)}}{144\pi} \text{ c/sq. in.}$$

For the consideration of enclosed fittings a sphere was chosen and certain simplifying assumptions made in the preliminary calculations, they were:—

(1) A complete sphere was considered.

(2) A point source of light of known lumen output at the centre.

(3) Uniform thickness of glassware.

(4) Complete diffusion of both transmitted and reflected light.

For the calculation, four factors are necessary, the transmission and reflection factors for directed light and for diffused light. From the lumen output of the source and the direct transmission factor, the number of lumens passing through the glass due to the light impinging on the inner surface direct from the lamp can be determined. Similarly, from the direct reflection factor and the lumen output of the lamp the light diffusely reflected across the sphere can be determined. At each subsequent incidence of this reflected light, the diffuse transmission and reflection

*For further information see "Jour. Soc. Glass Technology, 1942." (Presidential Address by S. English.)

factors give the amounts passing out of and remaining within the sphere respectively. The amounts transmitted, being a constant fraction of the amounts left in the sphere, can be summed as a geometric series, thus giving the total lumen output due to the light diffusely reflected across the sphere. The two transmissions thus determined, when added together, give the total lumen output of the fitting, from which the lumen output ratio can be derived. By dividing the transmitted lumens by 4π and the area of the spherical surface, the brightness as equivalent foot candles can be determined, and this in turn can be reduced to candles per square inch by dividing by 144π.

Further consideration of this process showed that a short cut was possible and the procedure reduced to the operation of a single formula:—

$$\text{Lumen output ratio} = T_{(dir)} + R_{(dir)} \left(\frac{T_{(diff)}}{1 - R_{(diff)}} \right)$$

where $T_{(dir)}$ = direct transmission factor.
$R_{(dir)}$ = direct reflection factor.
$T_{(diff)}$ = diffuse transmission factor.
$R_{(diff)}$ = diffuse reflection factor.

Allowances to be made for the practical impossibility to keep to the ideal conditions assumed in these calculations were considered, especially those due to—

(a) the non-uniform light distribution of the light from a filament lamp;
(b) the necessity for a neck aperture;
(c) shapes other than spherical.

Incidentally, these calculations under item (b) showed how very necessary it was to keep neck apertures of diffusing globes as small as possible, if the light output ratio was to be kept high; for example, a 10-inch sphere (complete) had a light output ratio of 81 per cent.; with neck apertures of 5 inches and 4 inches, it was reduced to 66 per cent. and 72 per cent. respectively.

Additions to List of Members.

The following applicants have been duly elected by the Council to membership in the Society, and their names have been added to the list of members:—

SUSTAINING MEMBER:—

Allom Brothers, Ltd.,*Lombard Road, Merton, LONDON, S.W.19.
Representative: J. E. Baker.

Bristol Gas Company, Radiant House, BRISTOL, 1.
Representative: Noel S. Smith.

CORPORATE MEMBERS:—

Adams, H. F.....11, Croham Road, Crowborough, SUSSEX.
Aslin, C. H. .....Gower Street, DERBY.
Baker, W. J. .....32, The Boulevard, WESTON-SUPER-MARE.
Bateman, G. O.....140, Winchmore Hill Road, LONDON, N.21.
Beatson, K. .....Beatson and Co., 21, Mowbray Street, SHEFFIELD.
Bennett, F. C. .....2, Mount Beacon, BATH.
Bowles, H. C. .....47, Macdonald Road, LEICESTER.
Brownsdon, J. B. W...19, Belle Walk, BIRMINGHAM, 13.
Clark, R. P. .....6, Lydon Road, Old Town, Clapham, LONDON, S.W.4.
Coates, F. H. .....Ministry of Supply, S.R.I., Berkeley Court, Gleetworth Street, LONDON, N.W.1.
Desborough, J. W. H. 19, East Lea Road, Weston, BATH.

* Resumption of Membership.

ADDITIONS TO LIST OF MEMBERS

CORPORATE MEMBERS:—*(continued)*

Dummer, F. W. ..... 196, Galpins Road, Thornton Heath, SURREY.
Elphee, G. H. ..... 125, Victoria Road, Oldbury, BIRMINGHAM.
Favell, J. E. ..... 22, Eldon Square, NEWCASTLE-ON-TYNE.
Fells, D. W. ..... 29, Rosedale Road, SHEFFIELD, 11.
Filer, S. L. ..... 84, Park View, Tredegar, MON.
Franck, C. ..... Holophane Company, Inc., 342, Madison Avenue, NEW YORK, U.S.A.
Gilbert, W. ..... 50, Sidegate Lane, Ipswich, SUFFOLK.
Herod, E. ..... 94, Bangor Street, DERBY.
Jackson, G. E. ..... 41, Keythorpe Street, LEICESTER.
Johnson, H. ..... 17, Aberdale Road, LEICESTER.
Kiefert, L. C. ..... 35, Marshall Grove, Erdington, BIRMINGHAM, 22C.
Kinch, W. A. ..... 42, Cecil Avenue, Hornchurch, ESSEX.
Lanham, J. K. ..... 17, Hillside Rise, Northwood Hills, MIDDLESEX.
Martin, H. S. ..... 70, Gower Road, Quinton, BIRMINGHAM, 32.
Martin, W. K. ..... 38, Villiers Road, Woodthorpe, NOTTINGHAM.
Martyn, A. E. ..... 146, Heavitree Road, Exeter, DEVON.
Nuttall, G. F. ..... 19, St. James's Street, DERBY.
Pitman, A. S. ..... 76, Goitre Fach Road, Killay, SWANSEA.
Ripley, H. P. ..... 5, Sunny Bank Road, Edgerton, HUDDERSFIELD.
Roberts, H. W. ..... 118, Preston Old Road, Cherry Tree, BLACKBURN.
Robertson, R. ..... 12, Cotham Park, BRISTOL, 6.
Shephard, W. H. ..... 70, Sandringham Road, Dalston, LONDON, E.8.
Townsend, J. W. ..... 44, High Street, TUNBRIDGE WELLS.
Wood, N. D. ..... White Ladies, Kilburn, DERBY.
Wotton, L. F. ..... 16, Severn Street, LEICESTER.

ASSOCIATES:—

Anderson, G. ..... "Burnbrae," SELKIRK.

STUDENTS:—

Blanchard, A. F. ..... 25, Water Orton Road, CASTLE BROMWICH.
Bryson, E. A. ..... 219, Harden Road, BLOXWICH.
Dixon, L. A. ..... 47, Caldwell Road, Bordesley Green East, BIRMINGHAM, 9.
Hulme, R. ..... Sadler Gate, DERBY.
Mewis, A. P. ..... 158, Glastonbury Road, Yardley Wood, BIRMINGHAM, 14.
Perriam, L. T. ..... 14, Wellesbourne Grove, STRATFORD-ON-AVON.
Rudd, E. P. ..... 66, Southern Road, STRATFORD-ON-AVON.
Vallance, D. K. ..... 31, Whitehouse Road, Cross Heath, Newcastle-under-Lyme, STAFFS.
Whitehouse, G. G. ... 3, Doris Road, Sparkhill, BIRMINGHAM, 11.

LIST OF I.E.S. REGIONAL COMMITTEES—*(continued)*

GROUPS:

BRADFORD GROUP (NORTH MIDLAND AREA).
Chairman: W. H. Naylor. *Hon. Secretary:* A. J. Hutchison. *Committee:* W. Ineson, J. Longthorne, H. Moss, G. Mountain, J. H. Rogerson, H. A. Shackleton, A. Southern, F. S. Warburton.

DERBY GROUP (MIDLAND AREA).
Chairman: F. H. Pooles. *Hon. Secretary:* C. S. Wheeler. *Committee:* C. H. Aslin, W. H. Buxton, L. A. Doxey, V. A. Gilman, M. R. H. Sadler, E. Jewitt.

LEICESTER GROUP (MIDLAND AREA).
Chairman: W. I. Hodgkins. *Vice-Chairman:* D. G. Woolfenden. *Hon. Secretary:* G. Bingham. *Committee:* E. H. Billing, S. C. Ginno, H. H. S. Mansfield, J. Martin, F. A. Smith, T. Wilkie, A. V. Wilson.

SESSION 1943—1944

LIST OF I.E.S. REGIONAL COMMITTEES

AREAS:

MIDLAND AREA.

Chairman: W. J. G. Davey. *Secretary:* C. J. Allderidge. *Committee:* C. S. Caunt, A. Hacking, J. Martin, F. H. Pooles, A. J. Pashler, W. J. P. Watson.

NORTH MIDLAND AREA.

Chairman: W. G. Thompson. *Secretary:* R. Pye. *Asst. Secretary:* J. A. Whittaker. *Committee:* J. T. Grimshaw, A. Kelso, J. W. Howell, J. H. Mollan, E. G. R. Taylor.

(In other Areas the only existing Centre Committee serves as the Area Committee.)

CENTRES:

BATH AND BRISTOL CENTRE (WESTERN AREA).

Chairman: J. B. Harris. *Vice-Chairman:* E. J. Ireland. *Joint Secretaries:* R. E. Tucker, and D. J. Sawkins. *Hon. Treasurer:* S. M. Richman. *Committee:* R. S. Hazell, W. A. Laughton, Miss E. L. Lee, Mrs. M. B. Probst, L. C. Rettig, W. Rush.

BIRMINGHAM CENTRE (MIDLAND AREA).

Chairman: A. J. Pashler. *Vice-Chairman:* J. G. Holmes. *Hon. Secretary:* C. J. Allderidge. *Hon. Treasurer:* F. F. Middleton. *Committee:* F. L. Cator, P. Hartill, J G. Holmes, R. Hulse, H. A. Keeling, R. Mackenzie, C. F. Partridge, W. E. Prendergast, T. H. Varcoe.

CARDIFF CENTRE (SOUTH WALES AREA).

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GLASGOW CENTRE (SCOTTISH AREA).

Chairman: J. Dickson. *Vice-Chairman:* E. M. Hood. *Hon. Secretary and Treasurer:* M. W. Hime. *Committee:* L. Fletcher, F. Hailstones, F. M. Hale, J. M. Henshaw, J. Lawrence, D. Macfarlane Macleod, A. M. Rankin, J. H. Scott, E. J. Stewart.

LEEDS CENTRE (NORTH MIDLAND AREA).

Chairman: A. Kelso. *Vice-Chairman:* E. C. Walton. *Hon. Secretary:* R. Pye. *Hon. Asst. Secretary:* A. Grocott. *Hon. Treasurer:* H. W. Harris. *Committee:* J. G. Craven, A. E. Elson, A. E. Fowler, D. C. Henderson, T. C. Holdsworth, J. H. Jackson, A. J. Johnson, J. H. Mollan, A. Southern, A. Wilde.

MANCHESTER CENTRE (NORTH-WESTERN AREA).

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Chairman: A. Hacking. *Vice-Chairman:* E. G. Phillips. *Hon. Secretary:* C. S. Caunt. *Hon. Treasurer:* E. Howard. *Committee:* C. C. Barnes, A. C. Collard, J. C. Charity, G. C. Hadfield, A. E. Kidd, C. C. Small, T. E. S. Thwaite, R. Gillespie Williams. *Ex Officio:* G. D. Johnson, M. Wadeson.

SHEFFIELD CENTRE (NORTH MIDLAND AREA).

Chairman: J. T. Grimshaw. *Hon. Secretary:* J. A. Whittaker. *Hon. Asst. Secretary:* D. H. Fox. *Hon. Treasurer:* W. Berry. *Committee:* A. Blake, R. Hillier, H. B. Leighton, N. Schofield, H. E. W. Selby, E. G. R. Taylor, W. G. Thompson, F. J. E. Walker.

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